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Near infrared diode laser spectroscopy for atmospheric molecules

Pradip N Ghosh
Department of Physics, University of Calcutta, 92, Acharya Prafulla Chandra Road, Kolkata-700 009, India
E-mail : png@cubmb.ernet.in

Abstract : Near infrared semiconductor diode lasers are used for high resolution and high precision measurements on atomic and molecular physics. General characteristics of diode lasers and a diode laser spectrometer based on commercial diodes are presented. Line shape measurements on small atmospheric molecules have been carried out to obtain line broadening, narrowing and line strength parameters.

Keywords : Laser spectroscopy, atmospheric molecules

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1. Introduction

Tunable diode lasers are widely used for research in atomic and molecular physics. Dye lasers so far dominated the field of high resolution spectroscopic studies. However, tunable dye lasers need a pump laser which requires high voltage power lines. They are very expensive and need a large laboratory space. These lasers also have a number of internal optical elements which can be easily misaligned. On the other hand, semiconductor diode lasers do not need separate pump laser and have no internal optical elements. Being electronic devices they are capable of source modulation. Near infrared diode lasers can be used at room temperature. So they are inexpensive and require small laboratory space so that one can afford multiple laser experiments. Infrared diode lasers based on lead salt semiconductors are more expensive as they require cooling to temperature of the order of 10–30 K. A serious problem of all diode lasers is mode break and low power. They cannot be continuously tuned for long wavelength range and also for experiments which need high power. Some special measures are taken in the case of external cavity diode lasers or in the high power master oscillator power amplifiers.

In this paper, we shall discuss a high resolution spectrometer based on near infrared diode lasers and its use in spectral studies of atmospheric molecules.

2. Near infrared diode laser spectrometer

We have set up a near infrared spectrometer based on GaAlAs diode lasers emitting in the 750–850 nm region [1]. Diodes obtained from Mitsubishi or Hitachi can emit over a range of nearly 20 nm. In this region it can have 10–20 dark regions. A typical mode has a size of 6–8 cm^{-1}. The diodes can lase in the temperature range of 10–60°C and operate at a threshold current above 45 mA and have a limiting current of 80–100 mA. A Peltier element attached to the diode case is used to change the temperature under controlled conditions and is used for tuning the laser wavelength. The laser frequency can also be fine tuned by changing the diode current. The current can be modulated by applying an *rf* signal at 2–5 kHz. This leads to frequency modulation of the laser output. The line width of the laser can be extremely narrow depending on the temperature fluctuation. The diode laser is normally used in maximum power emitting region of a mode. Thus it can be operated in a single mode.

The laser radiation is detected by a Si photodetector obtained from United Detector Technology, USA with an integrated preamplifier. The biasing circuit is designed in the laboratory, so that gain of the detector can be adjusted. The output from the detector is fed to a lock-in amplifier from SRS instruments for phase sensitive detection with the reference from an *rf* oscillator. The digital signal is stored in a PC. The laser beam is divided into two parts by a beam splitter. One part goes through a sample cell and the other goes through a reference cell for baseline correction. They are fed to the ratio inputs of the lock-in amplifier. The laser beam is also further subdivided before going to the cells so that a part is passed through an air-spaced etalon and another part goes through a monochromator. The etalon with an FSR of 5.00 GHz and a finesse value of 36 is used for mode selection and relative calibration of frequency. The monochromator provides the approximate wavelength. The actual wavelength can be obtained from a known transition. The cells are made of glass with glass windows

3. Line shape measurements

The second derivative spectrum recorded with this spectrometer [1] is transformed to the absorption spectrum through a numerical integration procedure. For simulation of the spectral lines we have first used the Voigt profile. To consider the effect of collisional narrowing we have used soft collision Galatry model containing an additional parameter defined to be the narrowing coefficient arising from the velocity changing collisions. The absorption intensity computed from Beer-Lambert's law is then convoluted with a Lorentzian function to consider the laser line width and other instrumental contributions.

We shall report measurements of line shapes of rovibronic components of the atmospheric A-band of oxygen and an overtone-combination mode of acetylene in presence several foreign gas perturbers.

4. Conclusions

Inexpensive commercial diode lasers have been used in recent years for high resolution tunable diode laser spectroscopy. The main features that have made such lasers most attractive are the following : (i) room temperature operation requiring no cryogenic facility, (ii) very little input power for operation, (iii) very long lifetime, nearly 10000 hours of operation, (iv) extremely narrow bandwidth of the order of 100 kHz or less in the case of external cavity diodes, (v) very stable power output with little noise, (vi) small size of the laser and the power supply and (vii) low price and cost of operation compared to all other tunable lasers with similar performance. This long list of advantages of the near infrared diode lasers preponderates over the major problem of mode hops in these diodes. This problem of mode hopping is solved in the external cavity diode lasers which can be tuned over long ranges with a very low laser line width of nearly a kHz. The spectroscopy problems that can be solved with these lasers are mostly the vibrational overtones and some of the electronic transitions of molecules and the electronic transitions of atoms. We have demonstrated that spectrometers based on commercial near-infrared diode lasers can be used to obtain high precision information about line broadening, collisional narrowing and line strength parameters. Frequency stabilized diode lasers are being used in our laboratory for studying nonlinear processes like Lamb dip phenomena and optical-optical double resonance using two diode lasers

References

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